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# *Contents*

## The Editor's Page

### Biology:

Current Concepts of Mitosis.

John J. G. Alexander, S.J.

Fordham University, New York, N.Y.

### Chemistry:

Proposed Mechanism for the Thermal Decomposition of Alkyl

Trimethyl in the Presence of Hydrogen.

Clarence C. Schubert, S.J.

Canisius College, Buffalo, N. Y.

Maxwellian Demon At Work.

Rev. Bernard A. Fiekers, S.J.

Holy Cross College

### Mathematics:

Laplace Transformations in Linear Systems.

Stanley J. Bezuszka, S.J.

Weston College

### Physics:

10 Watt Audio Amplifier.

C. F. Turner, S.J.

### News Items:

Boston College: Biology Department

Canisius College: Chemistry Department

Holy Cross College: Chemistry Department

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## *The Editor's Page*

With the publication of the May-June Issue of this year, Volume 24 will be completed. Because some members of the Association may be away from home on summer work when the last Issue arrives, the Editor takes this occasion to call to the attention of all that next year will be the twenty-fifth consecutive year of publication for the Jesuit Science Bulletin. Plans should be made for a commemorative Issue or even complete volume. The form this will take should be high on the agenda for the general meeting this coming summer. Think it over and have your suggestions when we get together.

The Editor's mail recently brought Vol. 1 No. 2 of the "Ricerche Astronomiche" published by the Vatican Astronomical Observatory. The entire Number is given to an article, "The Harvard Variable Star Fields" by Rev. Walter J. Miller, S. J.

The BULLETIN at this time records the untimely death of Rev. Clarence E. Shaffrey, S. J., professor of Biology at St. Joseph's College, Philadelphia. It is hoped to have a more complete Obituary in a later Issue. R.I.P.

This and the previous Issue of the BULLETIN have been mailed with the new mailing list taken from the membership list compiled according to the plans made at the last general meeting. The Editor feels sure copies of these Issues have been sent to each house through the country. Inevitable omissions can now be rectified by a notice to the Editor.

# Biology

## CURRENT CONCEPTS OF MITOSIS

JOHN J. G. ALEXANDER, S.J.

(The author is indebted to Rev. C. A. Berger, S.J., Ph.D., Head of the Department, for his kind permission to use the material of his lectures.)

MITOSIS is that type of nuclear division in which chromosomes divide longitudinally and are distributed evenly to the daughter nuclei. Usually, but not always, cell division accompanies and concludes the process.

The significance of the process rests in the fact that chromosomes may well be considered "as the most important material bodies in the universe." (Berger 1942). The science of Genetics has abundantly demonstrated that chromosomes are the material basis of hereditary differences. Moreover, growth and differentiation as well as development normally involve cell division. The special cases where cell division does not occur need not concern us here. The bearing of Cytology on Genetics and of Genetics on human welfare are sufficient reason for a careful study of mitosis, the process responsible for chromosomal transmission from cell to cell and from generation to generation.

Chromosomes were first seen about 1878, and since then the usual methods of study include (1) staining of cells at various stages of development, (2) special treatments of cells (colchicine for example), and (3) in Genetics, experimental breeding.

The process of mitosis is comprised of a great complex of different mechanisms, and while there are as yet many unsolved problems connected with it, certain facts have come to light that dissipate the fog of many former errors.

The so-called "resting stage" is an inaccurate description since it is now known that during this stage, chromosomes are most probably actively duplicating themselves. Berger (1938) working on the larva of the mosquito, *Culex pipiens*, and others, have shown that most probably it is during the resting stage that chromosomal re-duplication takes place. The other term suggested for this "resting" phase is "metabolic." This too has its limitations since it implies a physiological quiescence during the very active cycle of division.

*The Resting Nucleus* is surrounded by a membrane and contains an *apparent* reticulum of the coiled and twisted chromonemata. One or more nucleoli are visible, and sometimes *prochromosomes* may be seen. These are portions of chromosomes that have remained condensed from the previous division. These prochromosomes and other "chromo-centers" or staining portions of chromosomes in the resting nucleus disprove the older idea that chromosomes disappeared during resting stage. They do not. They remain in the nucleus. They merely lose their staining ability. A "relic coil" persists in a chromosome through resting stage, the process of de-spiralization at end of telophase not having been completed.

At Prophase the *apparent* reticulum disappears. Chromosomes appear at early prophase as long thin threads or chromonemata. From prophase to metaphase the chromosome decreases in length and increases in diameter. This contraction is due to spiralization or coiling. Here it must be stated that chromosomes never lose their identity, but from one division to another remain distinct. They do not form one continuous thread or "spireme" of the earlier literature, but remain distinct and disparate structures. In favorable cases, when chromosomes are first seen they appear as doubled structures, somewhat like the double barrel of a shotgun, the two "barrels" joined together but distinguishable by a median longitudinal furrow.

By mid-prophase chromonemata are seen to be embedded in a matrix, a non-staining portion. The nucleolus also changes, staining more deeply.

During *rather late prophase* the nuclear membrane usually disappears and the spindle forms. Schrader (1944) after discussing the evidence on both sides, concludes that the reality of the spindle fibers can no longer be doubted. Here the relic coil is lost, and a new coiling or spiralizing occurs throughout the length of each chromosome.

*Pro-metaphase* begins when the chromosomes have reached their maximum of condensation and spiralization. The chromosomes are still irregularly distributed through the cell. But now they move to the equatorial plane in the center of the cell. This first movement is called *congression*, and it is noteworthy that chromosomes can, do and must move to get to the plate.

*Metaphase* is the stage when chromosomes become attached to the plate and separate along their lengths. They attach to the metaphase plate by their "spindle-attachment regions" or, more briefly, as suggested by Berger (1946), "SA-regions." This is a specially differentiated area of the chromosomes, the position of which along their length determine their shapes at metaphase and after. The usual shapes, are V, when the SA-region is central, J, when the SA-region is to either side of center, and Rod, when the SA-region is terminally located. The dot-shaped chromosomes are believed to be short but extended structures with centrally located SA-regions, and there is much doubt that any—even the rod—chromosomes have strictly terminally located SA-regions.

Chromosomes at metaphase are clearly seen to be "double-barreled" and one somatic metaphase chromosome is equal to 2 chromatids. As soon as the chromatids separate they cease to be chromatids and become chromosomes. Ordinary textbooks would say that chromosomes "split" at metaphase. Chromosomes *never split*. The process which used to be called *splitting* is twofold, 1) reduplication, and 2) separation of the reduplicated elements. The process of longitudinal separation occurs at metaphase.

*Anaphase* is the stage in which chromosomes separate completely from one another and then move toward the poles. The mechanisms involved are still not clearly understood, though many theories have been advanced. From the mass of accumulating evidence the current idea may be extracted, of a complex involving 1) elements of the spindle, 2) autonomy of the chromosomes, and 3) interaction of various forces. "Continuous spindle fibers" connect the poles, and "chromosomal fibers" connect with the SA-regions of the chromosomes themselves. At anaphase chromosomes repel each other and "interzonal fibers" connect these separating chromosomes.

Belar in 1929 claimed that this initial separation of daughter chromosomes is autonomous. But any movement beyond this initial separation is associated with the presence and activity of the spindle apparatus.

Various forces are postulated in many hypotheses to explain the movement of chromosomes to the poles. It is possible that the majority of these have elements of truth in them. Thus electrical changes of potential, hydration and de-hydration, diffusion and changes in viscosity and surface tension, are certainly forces at work in the ordinary life of the cell. Around these many hypotheses have been built. According to one of the oldest hypotheses, chromosomes are pulled to the poles by shortening of the spindle fibers. This could not explain all the phenomena and the idea lost popularity. But Schrader (1944) reports that Astbury and Bernal have recently suggested that the shortening of a spindle fiber and the contraction of a myofibril may involve the same fundamental mechanism, namely the folding of a polypeptide chain, or change in shape of a protein molecule. Schmied's experiments on birefringence of the living and fixed spindle at metaphase also indicate the protein nature of the fibers, as well as something of the nature of the mechanism that may be involved in anaphase movement. It is yet unsettled.

*Telophase:* At this stage the daughter chromosomes have reached the poles. Having reached this destination, chromosomes clump together in what is known as the "tassement polaire" condition. Next they open up, repel each other, absorb water and increase in viscosity. Then they unwind the spirals that had become most tightly coiled at metaphase, increase in length, but decrease in staining ability. They change to form "vesicles" as some call it. In most cases the vesicles fuse to form the "resting" nucleus.

The nature of the resting stage and the process taking place during this stage, cannot be studied in fixed preparations. White (1937) believes this is probably due to the high water content of the nucleus and chromosomes at this point. It is now however almost certain that during the "resting stage" chromosomes duplicate themselves, and become "double-barreled" again in preparation for the next division. For this direct evidence is presented by Berger (1938) reporting on the larva of *Culex pipiens*. Others too have supported this view with indirect evidence. The phenomena of polyploidy are best interpreted as double reduplication during resting. This is Berger's interpretation for polysomy in Spinacia (1941). This is indeed the most widely held opinion today, and can be predicated of all known cases of mitosis, since the first time chromosomes are visible they appear as clearly doubled structures, or double-barreled entities.

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The Standard Oil Company of New Jersey has reprinted from its publication The Lamp, three very interesting articles on synthetic rubber, "Butadiene", "Perbunan" and "Butyl". These articles are published under the title "Rubber from Oil" in convenient form for class distribution. Written in popular style and well illustrated with pictures and diagrams, this booklet gives to the general student an excellent summary of part of the work of this company in this field. This publication was not originally designed for educational purposes, but at the present time the Company is engaged in production of material for classroom use. Copies for distribution may be obtained by writing the Company.

# *Chemistry*

## PROPOSED MECHANISM FOR THE THERMAL DECOMPOSITION OF ALUMINUM TRIMETHYL IN THE PRESENCE OF HYDROGEN

CLARENCE C. SCHUBERT, S.J.

It was observed previously (1) that the apparent anomalous behavior of the decomposition of aluminum trimethyl in the presence of hydrogen required an explanation. In this paper a mechanism is proposed to explain why the presence of hydrogen should reduce both the rate of decomposition and the apparent energy of activation.

The addition of hydrogen to the reaction vessel resulted in a decrease in the overall rate of decomposition of the alkyl, and a slight increase in the ratio of methane to alkyl decomposed. On the assumption that the reaction was of the same order as that of the thermal reaction in the absence of hydrogen i.e. three halves order, the energy of activation calculated from the three halves order rate constants had a value of 30.5 kcal. Calculation of the energy of activation on the basis of a first order reaction gave a value not materially different, namely 29 kcal. The mechanism proposed here is that of a three halves order reaction.

It must be noted that the behavior of aluminum trimethyl in the presence of hydrogen is markedly different from that of mercury dimethyl (2) which decomposes faster in the presence of hydrogen than when hydrogen is absent, the accelerated rate increases with increase in the hydrogen pressure and mercury dimethyl consumes hydrogen in the process. In the case of aluminum trimethyl, the opposite effect becomes constant above a pressure value of about 15 mm. However, mercury dimethyl is similar to aluminum trimethyl inasmuch as the presence of hydrogen lowers the energy of activation in both cases. The mercury dimethyl reaction was studied at a pressure of 40 mm. alkyl pressure while the reaction involving aluminum trimethyl was conducted at alkyl pressures of about 15 mm. It is possible that at higher pressures the addition of hydrogen to the aluminum trimethyl would result in increased yields. At lower pressures the diffusion of the radicals to the walls of the vessel would be more significant and would, consequently, lower the yields of the decomposition products.

The reactions involved in the thermal decomposition in the presence of hydrogen would be as follows:

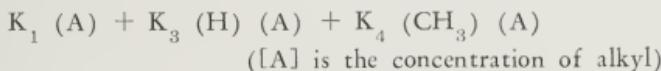
1.  $\text{Al}(\text{CH}_3)_3 \rightarrow \text{CH}_3 + \text{Al}(\text{CH}_3)_2$   
 $E_a = \text{about } 60 \text{ kcal.}$  (1)
2.  $\text{H}_2 + \text{CH}_3 \rightarrow \text{CH}_4 + \text{H}$   
 $E_a = \text{about } 9 \text{ kcal.}$  (2) (3) (4)
3.  $\text{H} + \text{Al}(\text{CH}_3)_3 \rightarrow \text{Al}(\text{CH}_3)_2 + \text{CH}_4$   
 $E_a = \text{about } 6 \text{ kcal.}$  (7)
4.  $\text{Al}(\text{CH}_3)_3 + \text{CH}_3 \rightarrow \text{CH}_4 + \text{Al}(\text{CH}_3)_2 \text{CH}_2$   
 $E_a = \text{about } 15 \text{ kcal.}$  (4) (5) (6)
5.  $\text{Al}(\text{CH}_3)_2 \text{CH}_2 \rightarrow \text{CH}_3 + \text{Al}(\text{CH}_3)_2 \text{CH}_2$   
 $E_a = \text{low}$  (7)
6.  $\text{H} + \text{H} \rightarrow \text{H}_2$   
 $E_a = 0 \text{ kcal.}$
7.  $\text{CH}_3 + \text{H} \rightarrow \text{CH}_4$   
 $E_a = 0 \text{ kcal.}$
8.  $\text{CH}_3 + \text{CH}_3 \rightarrow \text{C}_2\text{H}_6$   
 $E_a = 0 \text{ kcal.}$

In the thermal decomposition of aluminum trimethyl in the absence of hydrogen the principal means for the decrease in the concentration of the alkyl is, apparently, the reaction of the alkyl with methyl radicals. If the reaction of the alkyl in the presence of hydrogen differed from the reaction in its absence solely by the fact that the principal means for the decrease in alkyl concentration is the reaction of the alkyl with H atoms instead of methyl radicals, the energy of activation would be decreased. Thus, in the presence of hydrogen, the steady state concentration of radicals, both methyl and H, is equal to

$$\left( \frac{K_1[A]}{K_2} \right)^{1/2}$$

( $K_1$  is the rate constant for reaction 1,  $K_2$  for reaction 2, etc.) Since by reaction 2 every methyl radical is a potential hydrogen atom,

especially when  $H_2$  is in excess, the rate of decrease in alkyl concentration is equal to:



The decomposition due to reaction 1 and 4 would be very small in comparison with that due to reaction 3. Therefore if the concentration of methyl radicals,

$$\left( \frac{K_1 [A]}{K_2} \right)^{1/2}$$

is substituted for the hydrogen atom concentration, [H], the rate is equal to:

$$K_3 \left( \frac{K_1}{K_2} \right)^{1/2} [A]^{1/2}$$

Thus, the order for the reaction would be three halves, and the energy of activation for the entire reaction would be:

$$E_3 + \frac{1}{2} E_1 - \frac{1}{2} E_2 \quad \text{or}$$

$$6 + 30 - 4.5 \quad \text{or}$$

$$31.5 \text{ kcal.}$$

This agrees with the observed 30.5 kcal. calculated for the three halves order reaction.

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## MAXWELLIAN DEMON AT WORK

REV. BERNARD A. FIEKERS, S. J.

This is the title of an article which appeared in Industrial and Engineering Chemistry, advertising section p. 5, for May 1946. Although the literature that has thus far appeared on the topic may be familiar to chemists among us, its inclusion here is warranted for its fundamental importance in all science and for its interest to the philosopher.

In effect "hot" and "cold", or fast and slow, molecules can be separated by an ingeniously simple device, developed by Rudolf Hilsch at Erlangen in Germany, and brought to Johns Hopkins University in this country by R. M. Milton.

It consists essentially of a T tube of metal, less than twenty inches long arranged with various valves, and other obstructions to the flow of gas. The design of the tube seems to be most critical at the T joint.

By allowing gases under pressure to enter the tube at the T, hot air emerges from one end of the tube, while cold air, sufficiently cold under certain circumstances to cause frosting, emerges from the other end.

Industrial and Engineering Chemistry for December 1946, advertising section p. 5, carries another article on the device in which various explanations for its baffling behavior are offered.

The term, "Maxwellian Demon", has such a powerful influence on the imagination of the scientist, that it seems to have been abused in all but the most rigid literature of thermodynamics. This leads to confusion.

To quote Maxwell himself:<sup>1)</sup>

"One of the best established facts in thermodynamics is that it is impossible in a system enclosed in an envelope which permits neither change of volume nor passage of heat, and in which both the temperature and pressure are everywhere the same, to produce any inequality of temperature or of pressure without the expenditure of work. This is the second law of thermodynamics and it is undoubtedly true as long as we can deal with bodies only in mass, and have no power of perceiving or handling the separate molecules of which they are made up. But if we conceive a being whose faculties are

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<sup>1)</sup> J. Clerk Maxwell, London, Longmans Green & Co., 1871. This quotation is copied from the "Classic of Science," entitled, "Heat and Motion" which appeared in the Sci. News Letter, 22, no. 589, 55 (1932).

so sharpened that he can follow every molecule in its course, such a being whose attributes are still essentially finite as our own, would be able to do what is at present impossible to us. For we have seen that the molecules in a vessel full of air at uniform temperature are moving with velocities by no means uniform, though the mean velocity of any great number of them, arbitrarily selected, is uniform. Now let us suppose that such a vessel is divided into two portions, A and B, by a division in which there is a small hole, and that a being who can see the individual molecules, opens and closes this hole, so as to allow only the swifter molecules to pass from A to B, and only the slower ones to pass from B to A. He will thus without expenditure of work, raise the temperature of B, and lower that of A, in contradiction to the second law of thermodynamics."

Obviously, in the modern device, work is expended in the escape of gas from the higher to the lower pressure, and other conditions for the Maxwellian demon are not fulfilled.

It would seem that any increase in efficiency in this device will be limited in theory by the dictates of the second law, and in practice by the inconvenience of the slower and slower approach to "reversibility."

A so-called "Demon" of this kind has been constructed in the Chemical Engineering Department of Worcester Polytechnical Institute and really produces frost. Undoubtedly it will find many practical applications. It would be interesting to analyze the effluent gases from an air mixture to see if an oxygen-nitrogen differential also occurs. In that event, the data might lead to more substantial explanation of the Phenomenon.

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#### ERRATUM

Volume 24, No. 2, Dec., 1946. The title of the article by Fr. Fiekers reads, "A Satisfactory System for Dispensing Hydrogen Sulfate." This title should read, "A Satisfactory system for Dispensing Hydrogen SULFIDE."

# Mathematics

## LAPLACE TRANSFORMATIONS IN LINEAR SYSTEMS

STANLEY J. BEZUSZKA, S.J.

The operational method presented in this article is developed from the modern Laplace transformation viewpoint. As such, it possesses a greater unity and generality than the system of rules which were embodied in the conventional Heaviside Operational Calculus. Furthermore, the transformations will be restricted here to problems of linear constant-coefficient integrodifferential equations where the driving functions have bounded variation in every finite interval and possess general initial conditions. The simpler problems of this class were usually solved by three methods: 1) the classical, found in ordinary differential texts, 2) the Cauchy-Heaviside, 3) the Fourier transformation. At present, the Laplace Transformation offers the best general method and the greatest promise for further extension. The following is a brief formal introduction to the direct Laplace Transformation (*L*-Transformation) and some of its applications to specific problems.

The Laplace transformation is a functional transformation and may also be called a functional operator. We begin with a *definition* of the direct *L*-Transformation of some function  $f(t)$  and write

$$F(s) = \int_0^\infty f(t) e^{-st} dt \quad (1)$$

where  $\int$  stands for the integral sign, (lower limit zero, upper limit infinity)  
 $s=S+jw$   
 $t, S, w$  real variables.

The symbolic abbreviation of (1) is usually written as

$$F(s) = L[f(t)] \quad (2)$$

Now the integral transformation (1) provides a ready means for calculating the transform function  $F(s)$  corresponding to any given original function  $f(t)$  of the real variable  $t$ . Results of such functional correspondence are indicated in the Table of *Function-Transform Pairs*. In constructing such a table of pairs, the direct transformation is used to pass from a function  $f(t)$  in the column of 'Originals' to its corresponding transform  $F(s)$  in the column of 'Transforms'. In using such a table of pairs, one frequently moves in the opposite direction, that is, from a function  $F(s)$  in the column of 'Transforms' to its correspondent in the column of 'Originals', and

in so doing finds the inverse Laplace Transform of  $F(s)$ . The inverse Laplace transformation is indicated by

$$L^{-1}[F(s)] = f(t) \quad (3)$$

that is, if we are given a certain transformation, we reverse the process and find the given original function.

As the first 'Original', we shall consider the case where

$$f(t) = 1 \quad (4)$$

To find the  $L$ -transform of  $f(t)=1$ , we substitute for  $f(t)$  in (1) its indicated form in (4)

$$F(s) = \int_0^\infty e^{-st} dt \quad (5)$$

Integrating the right side of (5) (recalling the limits) and restricting the values of  $s$  to values greater than zero (i.e. positive values), we have

$$F(s) = L[1] = 1/s \quad (6)$$

Since the case of  $f(t)=c$  (where  $c$  is a constant) would not alter the integration process, we have immediately that the  $L$ -transform of  $f(t)=c$  is

$$F(s) = L[c] = c/s \quad (7)$$

and in the notation of equation (3), we have

$$\begin{aligned} L^{-1}[1/s] &= 1 \\ L^{-1}[c/s] &= c \end{aligned} \quad (8)$$

This method could be repeated for a variety of 'Originals' and the  $L$ -transform tabulated for future use in solving problems.

Besides its property of simplifying certain functions, the  $L$ -transformation has the much more important property of simplifying certain operations. Derivatives and integrals can be considered under this class. The derivation of the transform follows closely the method used in deriving the 'Function-Pairs', only our tabulated entries now read 'Operator-Transform Pairs'. As an example, suppose we investigate the  $L$ -transformation of the first derivative of  $f(t)$  with respect to  $t$  (and designate this latter by  $f'(t)$ ). Substituting  $f'(t)$  for  $f(t)$  in (1), and integrating (by parts), we find

$$F(s) = -f(0) + sL[f(t)] \quad (9)$$

where  $f(0)$  is the value of the function  
 $f(t)$  at  $t=0$ , and  $s$  is restricted  
 to positive values

Similarly, for the second derivative,  $f''(t)$ ,

$$F(s) = s^2L[f(t)] - f'(0) - sf(0) \quad (10)$$

where  $f'(0)$  is the value of the first derivative  
 of  $f(t)$  at  $t=0$ .

The  $L$ -transformation of the indefinite integral of  $f(t)$  is calculated in the same way and its transform can be found in Tables developed by Churchill: "Modern Operational Mathematics in Engineering", or Gardner and Barnes: "Transients in Linear Systems".

A Table of Function-Transform Pairs and Operator-Transform Pairs is given in the following section.

### FUNCTION-TRANSFORM PAIRS

	Original f(t)	Transform F(s)
1	1	1/s
2	k	k/s
3	exp. kt	1/(s - k)
4	cos kt	s/(s <sup>2</sup> + k <sup>2</sup> )
5	t	1/s <sup>2</sup>
6	t <sup>2</sup>	2/s <sup>3</sup>
7	sin kt	k/(s <sup>2</sup> + k <sup>2</sup> )
8	(1/k) (exp. kt - 1)	1/(s) (s - k)

### OPERATOR-TRANSFORM PAIRS

	Original f(t)	Transform F(s)
9	f'(t)	s L[f(t)] - f(0)
10	f''(t)	s <sup>2</sup> L[f(t)] - sf(0) - f'(0)

It will be well to pause in the development of new operational formulas for the purpose of illustrating their practical use. Take the case of the simple harmonic oscillator, where if  $x'$  and  $x''$  represent the first and second derivatives of  $x$  with respect to  $t$ , the equation of motion is

$$mx'' = -cx \quad (11)$$

where  $c$  is a positive constant initial conditions: at  $t=0$

$$\begin{aligned} x &= X \text{ (initial displacement)} \\ x' &= 0 \end{aligned}$$

We now rewrite eq. (11) in  $L$ -transformation form

$$m L[x''(t)] + c L[x(t)] = 0 \quad (12)$$

and using the Operator-Transform Table (#10), we have

$$m[s^2 L[x(t)] - s x(0) - x'(0)] + c L[x(t)] = 0 \quad (13)$$

Making use of the initial conditions and solving for  $L[x(t)]$ ,

$$L[x(t)] = (X) [s/(s^2 + c/m)] \quad (14)$$

Using the inverse relation in eq. (3) and the Function-Transform Table (#4), we have as the solution of the problem

Another example, which is practically identical in form and procedure, is the case of a projectile in a plane without air resistance. The equations of motion become

$$mx'' = -mg \quad \text{initial conditions: at } t=0 \\ x=0 \quad x'=V \cos a \\ y=0 \quad y'=V \sin a \quad (16)$$

and by the use of the  $L$ -Transformation, we solve at once for the parametric equations of motion.

In the case of electrical circuits (where the method has been used with great advantage), we can consider an L, R, E circuit where at time  $t=0$ ,  $i=0$ . The current equation becomes

where  $i'$  is the derivative with respect to t.  
E is constant

By the *L*-transform (Table #9)

$$L L[i'] + R L[i] = L[E]$$

Solve for  $L[i]$ , inserting initial conditions

$$L[i] = (E/L) [1/s(s + R/L)]$$

The inverse relation (#8) gives us

$$i = E/R = (E/R) \left[ \exp(-R/L)t \right] \quad \dots \dots \dots \quad (18)$$

Thus, in the one solution, we get the steady and transient states.

Although actually 30 years older than the Fourier Transformation, the Laplace transformation has not received as wide a use as its possibilities present. However, there is now an increasing use of the method in electrical and mechanical engineering which has prompted many teachers in mathematical physics and applied mathematics to introduce a simplified course for undergraduates.

The above discussion and illustrations scarcely do justice to the possibilities of the method. We must of course be cautious about becoming too excited about the range of applicability. So far, for example, it has not been extended with any advantage to non-linear problems.

# *Physics*

## 10 WATT AUDIO AMPLIFIER

C. F. TURNER, S.J.

The basic diagram for the amplifier described here may be found in the Radio Handbook, Edition Eight.<sup>1</sup> Many new ideas have been incorporated and changes made with the idea of obtaining a versatile laboratory amplifier. In general the unit consists of the following four stages: 1) Mixer, 2) Driver, 3) Power Amplifier, 4) Rectifier.

### THE MIXER STAGE

A dual input ( $J_1$  and  $J_2$  in Fig. I) uses 6SJ7 pentodes as mixer tubes. Each pentode with the full resistance of the gain control in the circuit should have a normal voltage gain of about 167.<sup>2</sup> These two inputs are so constructed that a microphone and a phono-pickup or two microphones may be used simultaneously. Input One ( $J_1$ ) is fed by way of a 1 megohm potentiometer ( $R_2$ ) through a 50,000 ohm resistor to the grid of the first 6SJ7. This 50,000 ohm resistor is used to reduce any possible tendency toward radio frequency pick-up when the amplifier is being used to produce a modulating voltage for a radio frequency generator or amplifier. Input Two ( $J_2$ ) is fed through a 500,000 ohm resistor in series with a 1 megohm potentiometer ( $R_5$ ) to the grid of the second 6SJ7. The 500,000 ohm resistor just mentioned has a switch ( $S_2$ ) in parallel. This resistor in the grid circuit is used as an attenuator<sup>3</sup> to reduce the gain of the stage in order that should we wish to mix the signal from a crystal pickup with the signal from a crystal microphone, both will have the same range of volume on their respective gain controls. If a pick-up is not used with this stage but another microphone instead, the switch is closed, shorting out the attenuator and so providing the higher gain necessary<sup>4</sup>. The single-pole-single-throw switch therefore provides a "High-Low" control over the voltage gain of the stage. The lower gain position is also useful when a carbon microphone is used. No provision, however, has been made in the amplifier for the direct connection of a carbon microphone because they are rarely used today. If however, it is desirable to use a carbon microphone the following arrangement is suitable. Connect in series, the microphone, a 4½ volt battery, a 400 ohm variable resistor and the primary of a microphone-to-grid

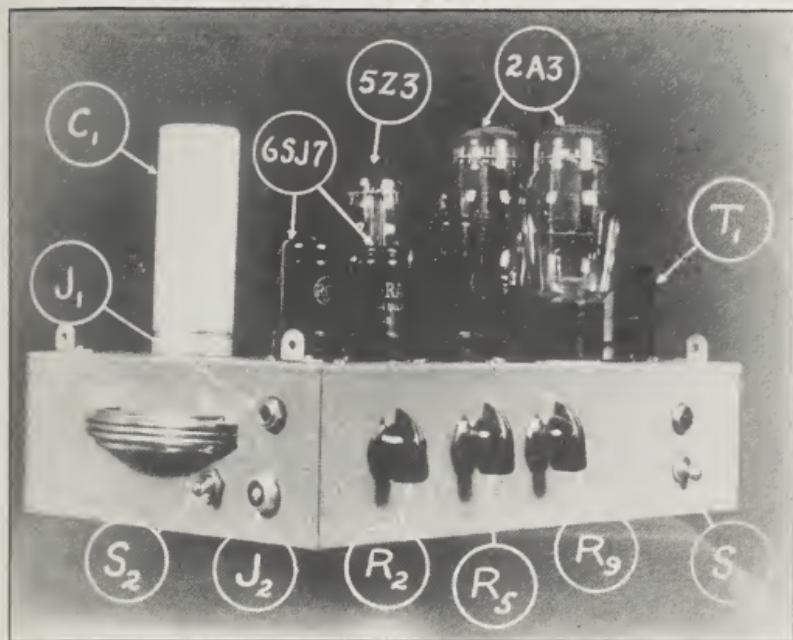


FIG. I

transformer.<sup>5</sup> The secondary of this transformer is then connected to  $J_2$ . Condenser, Velocity and Dynamic Microphones may also be used with either input.<sup>6</sup> Magnetic pick-ups will also give excellent results. If the magnetic pick-up is of the high impedance type it may be connected directly to either  $J_1$  or  $J_2$ . If it is of the low impedance type, a transformer having a low impedance primary and a high impedance secondary must be used.<sup>7</sup> The pick-up leads are connected to the primary of the transformer and the secondary to either  $J_1$  or  $J_2$ .

### THE DRIVER STAGE

Until recently push-pull input transformers were used to obtain the  $180^\circ$  out-of-phase voltages necessary for the grids of a push-pull output stage. However good quality push-pull transformers are expensive and now almost impossible to obtain. Moreover, since even the best transformers have a tendency to pick up inductive hum, a system of producing the out-of-phase voltages called Phase-Inversion is becoming more and more popular.<sup>8</sup> Many phase inverter circuits have been tried by the author but the so called "Floating ParaPhase" as used in this amplifier has always proved to be the most satisfactory for ordinary applications.

A pair of 2A3's, which we have chosen for the push-pull output stage, require a peak grid-to-grid swing of about 140 volts. Therefore a 6N7 was chosen as the driver tube, for each side of the phase inverter must be capable of an output of about 70 volts without appreciable distortion. One of the few small tubes that can deliver this is the 6N7 operating with 300 volts on each plate.<sup>9</sup> This 6N7 is a compact dual triode. With a plate voltage of 300 volts, a plate load resistance of 250,000 ohms and a grid biasing resistance on the following tube or tubes of 250,000 ohms, each section of the 6N7 has an output of approximately 80 volts, which gives a good safety margin over the 70 volts required.

A third control ( $R_6$ ) has been incorporated in the grid circuit of the first half of the 6N7. This is used to set the general level of the mixed signal which is being amplified.

### THE POWER AMPLIFIER

Although the original amplifier was constructed with 2A3's in the output stage, any triodes such as the 6A3, 6B4-G, or 6A5-G may be used with the proper heater voltage.

These final triodes are cathode-biased which necessarily limits their output to about 10 watts. Fixed bias could be used, but this would require batteries which would prove cumbersome not to mention the possibility of their needing renewal at the wrong moment. However, if one wishes, fixed bias may be easily incorporated. About 68 volts is required for the triodes mentioned above and the output will then be about 15 watts.

This output stage is loaded by the universal output transformer ( $T_1$ ) which has a 5000 ohm primary. The use of this type of transformer allows almost any speaker to work with good efficiency on the amplifier. The average speaker voice coil has an impedance of 8 ohms but speakers of different manufacturers differ from this value. The universal output transformer and the 2 gang 11-point rotary switch circuit allow the operator to match these different values. The rotary switch is used to combine the various taps on the secondary of the transformer. For the transformer used in this amplifier the impedances that may be selected are: 0.65, 1.0, 1.3, 2.0, 3.0, 4.5, 6.5, 12.5 ohms, giving impedance ratios, primary to secondary of: 7700, 5200, 3900, 2500, 1700, 1100, 770, and 400 respectively. This transformer is a Type R Universal built by United Transformer Company. There are many other universal output transformers on the market and they may be easily used in the amplifier with the selector circuit if the general idea of the system is used.

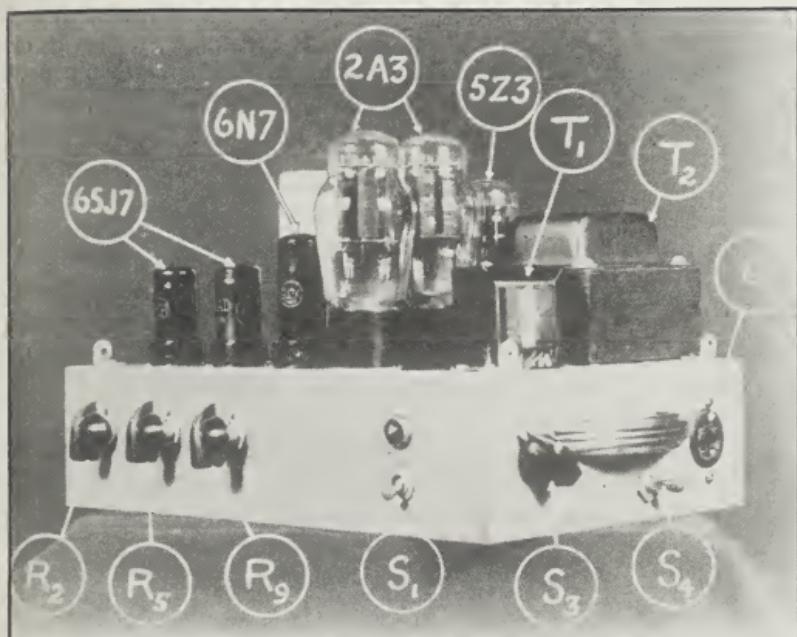


FIG. II

This selector switch ( $S_5$ ) may also be used as a tone control. The low frequencies will be accentuated if the switch is set to an impedance lower than is required for a perfect match with the speaker. The high frequencies will be accentuated if the switch is set to a higher impedance.

To provide a convenient connection for the voice coil of the speaker to the selector circuit, the rotor terminals of the switch ( $S_5$ ) are connected to the small receptacles of a 4 prong tube socket ( $O_1$ ). The large receptacles are reserved for power for a field coil, as will be described below.

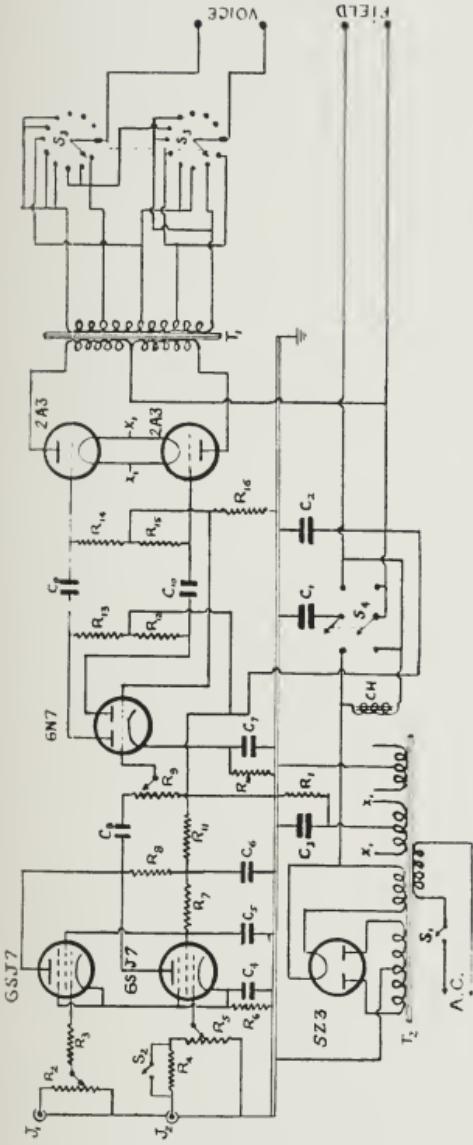
#### THE POWER SUPPLY

The power supply is the usual Full-Wave rectifier system<sup>10</sup> save for the double-pole-double-throw switch ( $S_1$ ) (Fig. II). This switch allows the amplifier to be used with either dynamic speakers, which require voltage and current for their field coil, or with permanent magnet type speakers which have no voltage or current requirement. The switch ( $S_1$ ) in one position puts voltage at the large receptacles of the 4-prong tube socket ( $O_1$ ) which may be used for the field coil of a dynamic speaker, and in the other, shuts off the voltage supply

to the socket. In reality it shifts the type of filter system, for in one position when a dynamic speaker is used the filter system is of the Series-Inductance type and in the other position (as when a permanent magnet type speaker is used) the filter system becomes the Shunt-Condenser type.<sup>11</sup> The transformer ( $T_2$ ) supplies all the power requirements of the amplifier. In series with the primary of this transformer the switch ( $S_1$ ) is used to turn the whole amplifier on or off.

The author wishes to thank both Father Henry M. Brock, S.J. who made the amplifier possible and Father Michael J. Ahern, S.J. for the photographs of the amplifier.

- 1—The "Radio" Handbook, Eighth Edition, 1941. Page 304. (Published by Editors and Engineers Ltd., 1300 Kenwood Road, Santa Barbara, California.)
- 2—For further discussion see, The Radio Amateurs Handbook, Twenty-third Edition, 1946. Page 127. (Published by American Radio Relay League, West Hartford 7, Conn.)
- 3—For Attenuator Theory see Terman, Radio Engineers Handbook, First Edition, 1943. Page 215. (McGraw Hill.)
- 4—While an output of 0.01 to 0.03 volt is average for a crystal microphone, a crystal pickup will average from 0.5 to 0.85 volt. Thus less gain is required for the pick-up. See Microphone Sensitivity, Radio Amateur's Handbook, op. cit. Pp. 125-127.
- 5—To match the grid in this input circuit the microphone-to-grid transformer should have a high impedance secondary. Cf. Radio Amateur's Handbook, op. cit. Pg. 126.
- 6—For methods of connecting various type microphones to an input tube Cf. Radio Amateur's Handbook, op. cit. Pg. 126, Fig. 512.
- 7—Low impedance line to high impedance grid.
- 8—Cf. 1. Phase Reversing, Terman, Radio Engineering, Second Edition, 1937, Page 308-309. (McGraw-Hill.)  
2. Excitation of Push-pull amplifiers, Terman, Radio Engineers Handbook, op. cit. Pg. 383.
- 9—Cf. R. C. A. Receiving Tube Manual, 1940, Page 129. RCA Manufacturing Co.)
- 10—Cf. 1) Terman, Radio Engineers Handbook, op. cit. Pg. 591.  
Cf. 2) Terman, Radio Engineering, op. cit. Pg. 478.  
Cf. 3) Radio Amateur's Handbook, op. cit. Pg. 176.
- 11—For full explanation of these individual filter systems Cf.  
1) Terman, Radio Engineers Handbook, op. cit. Pg. 606.  
2) Terman, Radio Engineering, op. cit. Pg. 483.  
3) Radio Amateur's Handbook, op. cit. Pg. 177-178.



C<sub>1</sub> - 4 mfd. 600 v. Elect.  
 C<sub>2</sub> - 8 mfd. 450 v. Elect.  
 C<sub>3</sub> - 50 mfd. 100 v. Elect.  
 C<sub>4</sub> - 10 mfd. 25 v. Elect.  
 C<sub>5</sub> - .1 mfd. 400 v. Tubular  
 C<sub>6</sub> - 8 mfd. 450 v. Elect.  
 C<sub>7</sub> - 25 mfd. 25 v. Elect.  
 C<sub>8</sub> - .005 mfd. 400 v. Tubular  
 C<sub>9</sub> - .01 mfd. 400 v. Tubular  
 C<sub>10</sub> - .01 mfd. 400 v. Tubular  
 R<sub>1</sub> - 750 ohms 10 watts  
 R<sub>2</sub> - 1 megohm potentiometer

R<sub>3</sub> - 50,000 ohms 1/2 watt  
 R<sub>4</sub> - 500,000 ohms 1/2 watt  
 R<sub>5</sub> - 1 megohm potentiometer  
 R<sub>6</sub> - 750 ohms 1/2 watt  
 R<sub>7</sub> - 1 megohm 1/2 watt  
 R<sub>8</sub> - 250,000 ohms 1/2 watt  
 R<sub>9</sub> - 500,000 ohm pot.  
 R<sub>10</sub> - 3000 ohms 1/2 watt  
 R<sub>11</sub> - 50,000 ohms 1/2 watt  
 R<sub>12</sub>, R<sub>13</sub>, R<sub>14</sub>, R<sub>15</sub> - 250,000 ohms  
 R<sub>16</sub> - 100,000 ohms 1/2 watt

T<sub>1</sub> - 5000 ohm pri. to univ.  
 secondary  
 T<sub>2</sub> - 700 v.c.t., 120 ma.; 5 v.  
 4 a.; 2.5 v. 5 a.; 6.3v.  
 2 a.

J<sub>1</sub>, J<sub>2</sub> - Input jacks  
 S<sub>1</sub> - S.P.S.T. Toggle (A.C.)  
 S<sub>2</sub> - S.P.S.T. Toggle  
 S<sub>3</sub> - 2 gang, 11 pt. rotary  
 S<sub>4</sub> - D.P.D.T. Toggle  
 CH - 15 hy., 125 ma. Choke

FIG. III

## *News Items*

### BOSTON COLLEGE BIOLOGY DEPARTMENT

Mr. Thomas I. Ryan and Mr. Francis L. Maynard have returned to the Biology Department of Boston College after a leave of absence during the war. The new members of the staff are Mr. Sylvio DiPietro and Mr. George Drury S.J. Seven Graduate and Senior Assistants devote nine hours a week to laboratory instruction.

On Feb. 3, 1947, thirty-six nurses of the new Boston College School of Nursing began a course in Zoology. In September, the Biology courses given in the School of Nursing will include Botany, Zoology, Microbiology, Anatomy and Physiology.

The Department has recently acquired a new horizontal, electric, automatic autoclave, ten monocular medical microscopes, twenty-five binocular wide-field dissecting microscopes, four kymographs, four inductoria and other equipment for the Physiology Laboratory.

Dr. Edward J. O'Donaghue of Chestnut Hill donated a microscope to the Biology Department. Dr. Thomas Barry, who died in the South Pacific while serving in the Navy, has bequeathed his library, microscope, a collection of lantern slides and other valuable material.

Plans are being made for a new Physiology Laboratory to accommodate the increasing number of students in the B.S. Biology course.

Mr. Leon Vincent and Mr. Thomas Ryan have just published a "Laboratory Manual for General Biology".

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### CANISIUS COLLEGE CHEMISTRY DEPARTMENT

CHEMICAL REVIEWS, Index, Volume 1 - 25. The Johnson Reprint Corporation, 125 East 23rd Street, New York 10, N.Y., announces, by means of a ten page author and topic index of the first twenty-five volumes of Chemical Reviews, their reprint of these volumes. This is done up in the same style as the indexes that appear at the end of each tenth volume. Since Chemical Reviews provide traditional background matter in academic research, seminar preparation and the like, it may be of value to include this complimentary item at the end of the twenty-fifth volume.

HOLY CROSS  
CHEMISTRY DEPARTMENT

Four new Master of Science candidates entered the graduate course on February 1, 1947, bringing the graduate enrollment in this department up to a total of twelve graduate students. Professors VanHook and Baril have received substantial grants from the Sugar Research Foundation. Dr. Baril is also engaged in some research for private industry and consultant for the Fallon Clinic in Worcester. Chemical Abstracts Author Index for 1946 lists eight publications or patents by alumni who since 1927 have graduated with the M.S. degree in Chemistry. This makes a total of one hundred and ten items over these years. The Benotti Brothers, Joseph and Norbert, who once worked in the Weston College laboratories, account for three of these items. On the evening of January 20, 1947, the department was host to the Worcester Chemists' Club. At the meeting Dr. Hudson Hoagland of the Worcester Foundation for Experimental Biology gave a very interesting illustrated lecture on Steroid Hormones in their relation to Behavior. There is a movement afoot in Worcester to establish a Worcester County Section of the American Chemical Society. The Reverend Frederic J. Moore, son of one of our faithful janitors in the department, was ordained to the Holy Priesthood for the Springfield, Mass. Diocese on January 19, 1947.

The occasion of answering a recent questionnaire for the National Research Council brought to light the fact that at least fifteen living alumni from the department have earned the Doctor's degree in chemistry: three from Georgetown and Clark Universities each; two from John Hopkins; and, one each from Boston University, Columbia, Iowa, M.I.T., Purdue, St. Louis and Yale. Eight of these received the Bachelor degree from Holy Cross; seven elsewhere. The degree of the late Fr. Francis W. Power, S.J., received from Fordham University, brings the total known number up to sixteen.

